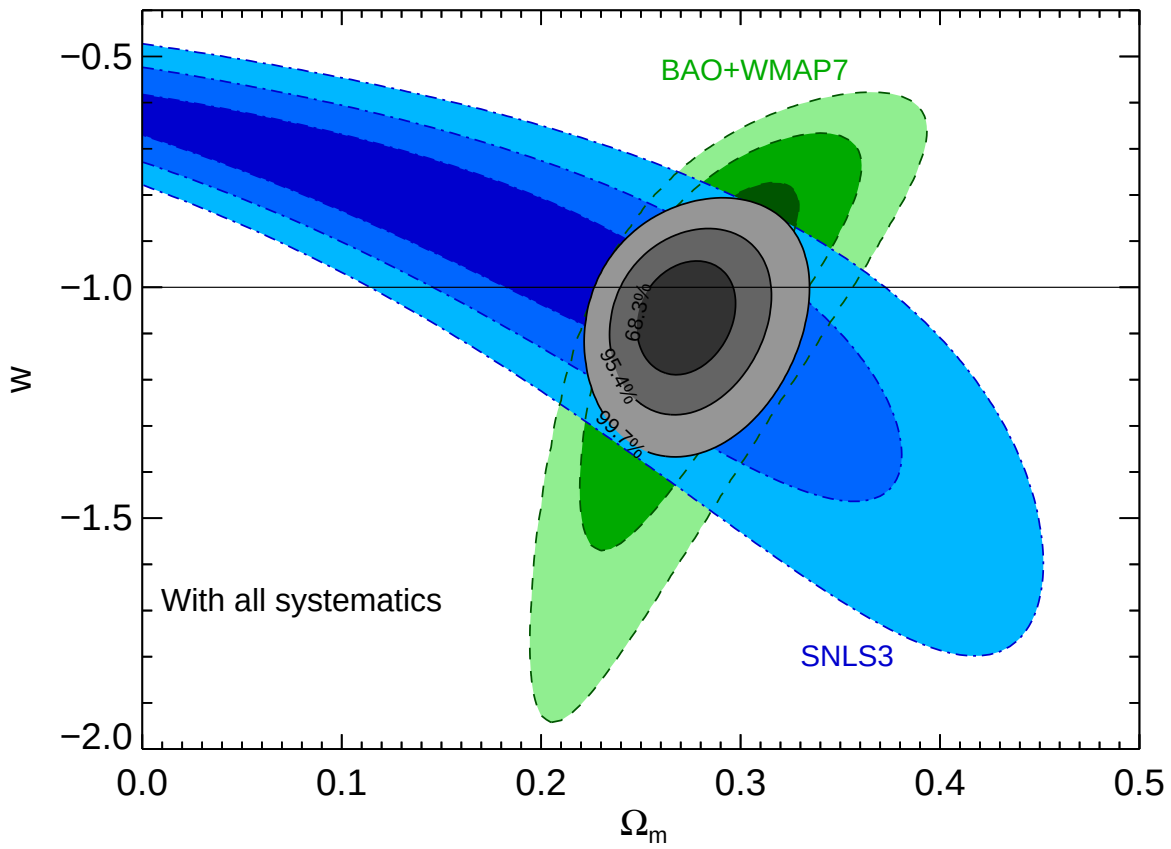
Calibration and cross-calibration of the SNLS and SDSS supernova surveys

Marc Betoule
SNLS collaboration, JLA collaboration, CFHT

LPNHE

Fermilab, Apr. 2012

Context and motivations



68.3%, 95.4%, 99.7% confidence contours FwCDM (Sullivan, 2011)

Cosmological constraint from type Ia SNe

- Most stringent constraints to date on the dark energy equation of state parameter $w = -1.021^{+0.078}_{-0.079}$.
- a ~ 2 improvement wrt CMB+BAO+H0

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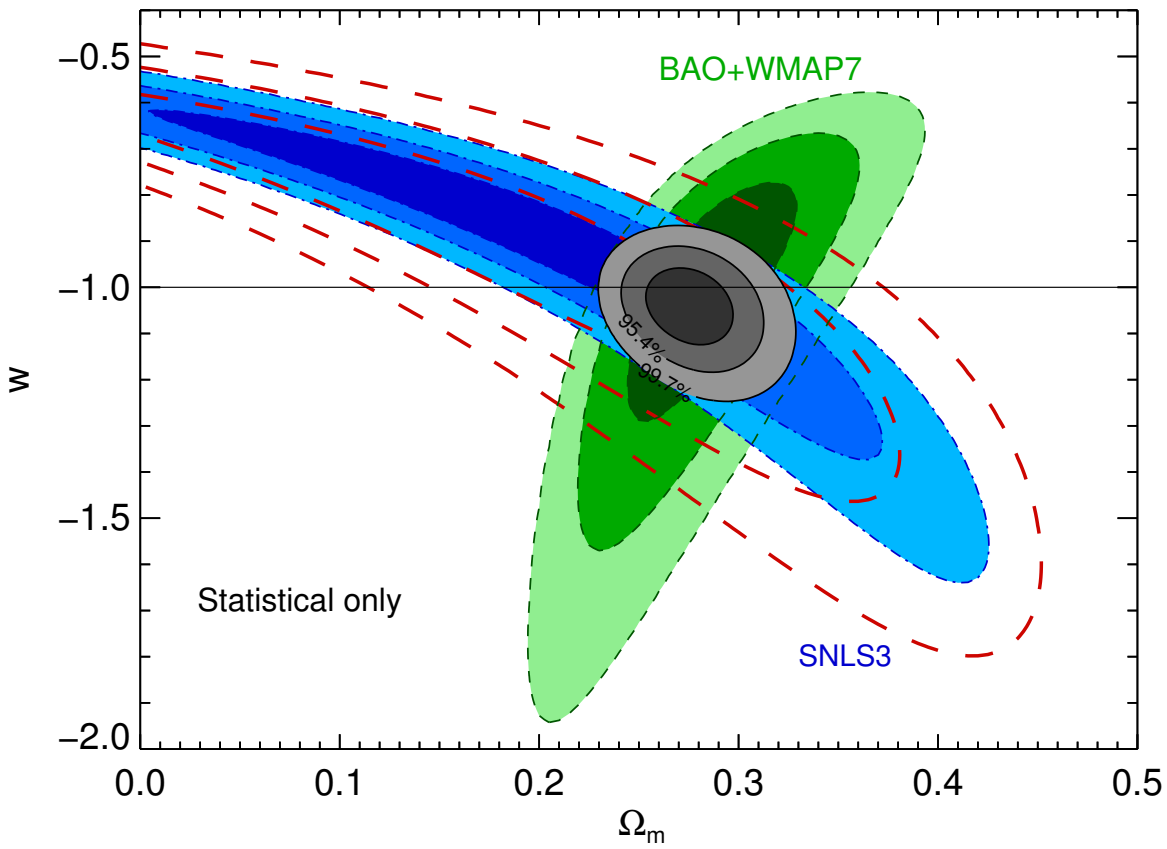

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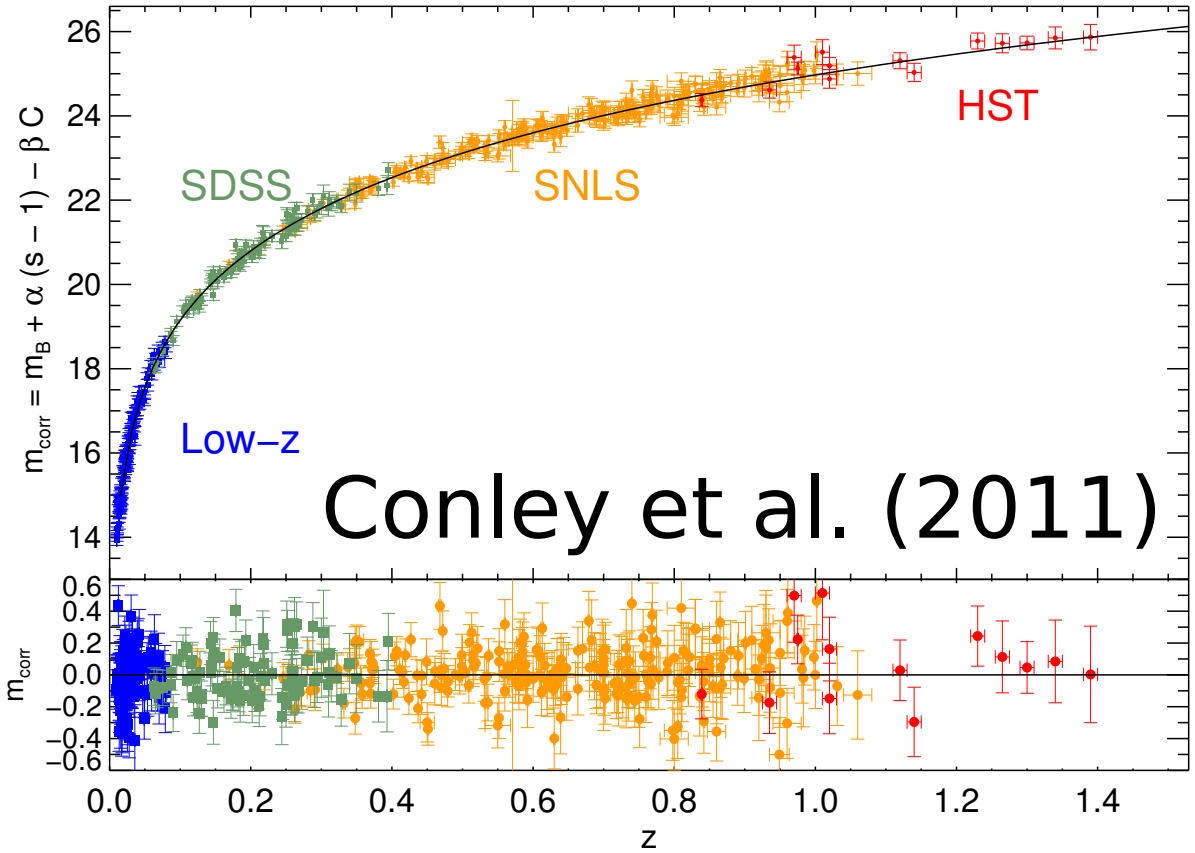
Photometric calibration is the main source of uncertainty

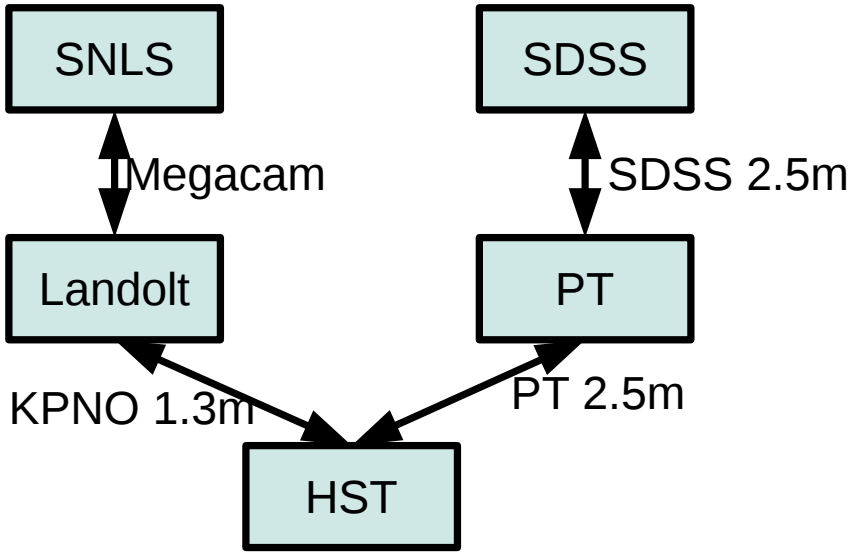
- $\sim 1\%$ reached in Regnault (2009)
- Need improvement for the final release

The type Ia SN Hubble diagram



- The luminosity of SNIae as a function of z: a precise photometry experiment (in average)
- Relative calibration between photometric bands *and surveys*
- 2 large similar surveys

Overview



Classic (star-based) calibration

- HST white dwarves as primary calibration source
- Transfer to in-situ tertiary standards

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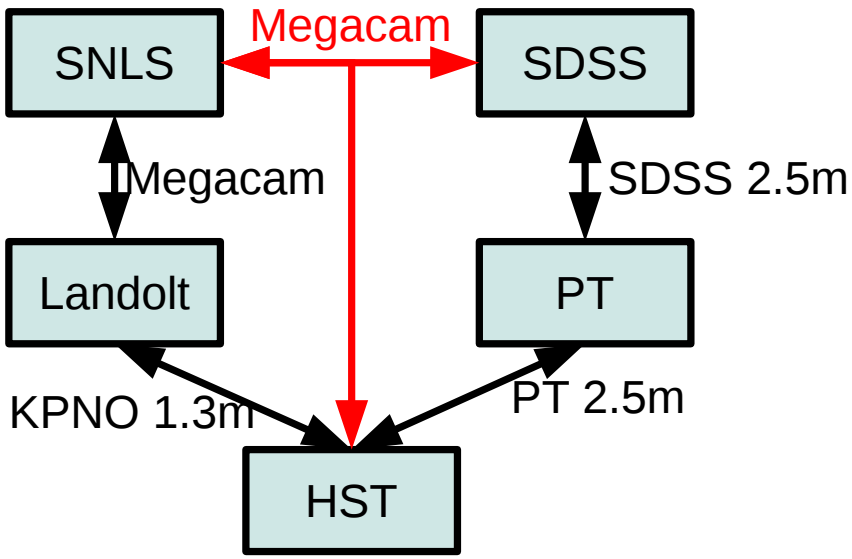


Classic (star-based) calibration

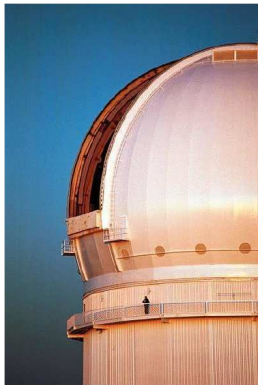
- HST white dwarves as primary calibration source
- Transfer to in-situ tertiary standards

Pushing this classic strategy

- Making the system redundant
- Shortening the calibration path
- Direct cross-calibration
- Cross-check of systematics

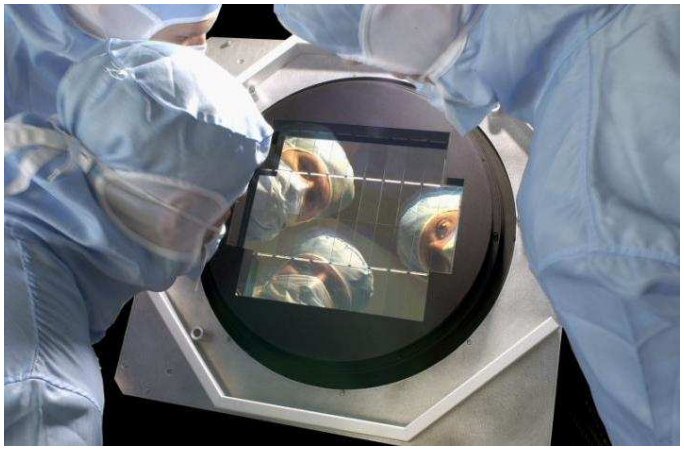
Outline

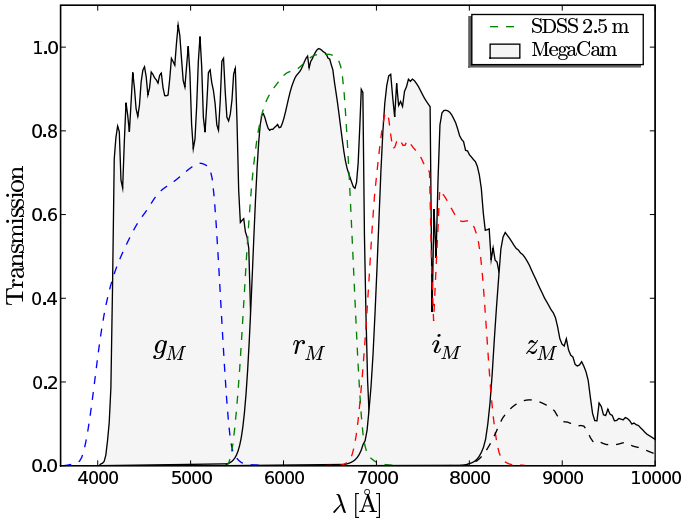
SNLS



Photometric survey at CFHT

- 3.6 m telescope
- 40 nights/year over 5 years
- 4 deep fields of the CFHTLS



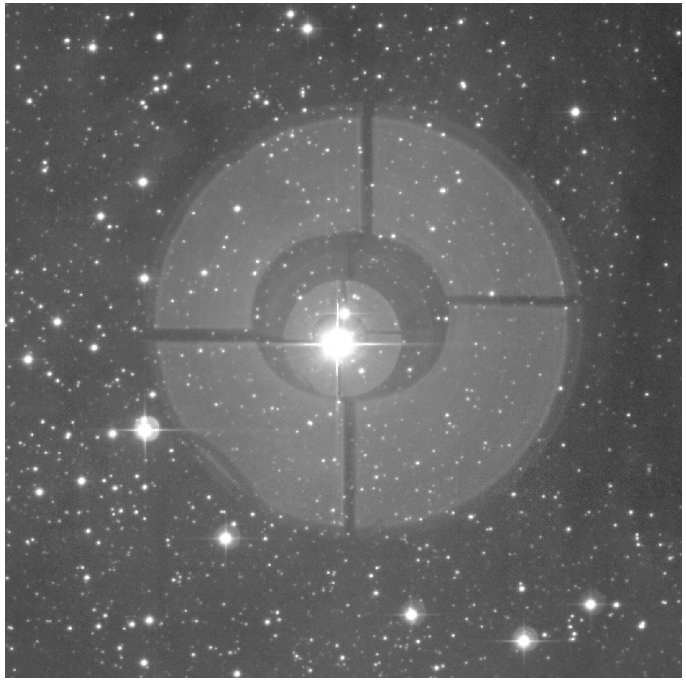


Megaprime/MegaCam

- 1 deg^2, $36 \times 2k \times 4.6k$ CCDs $\rightarrow$ 300Mpixels
- 4 photometric bands $g_M r_M i_M z_M$

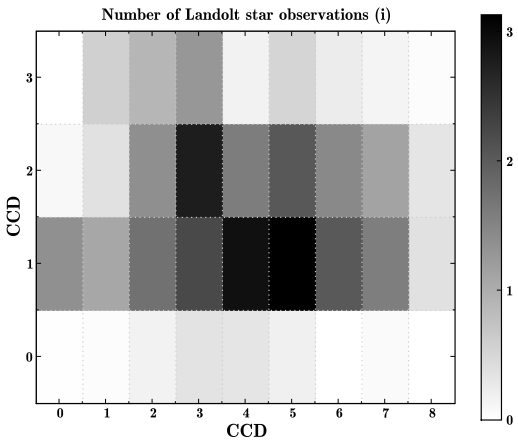
LPNHE PARIS

Step I: Mapping the instrument response



Twilight observations give wrong answers

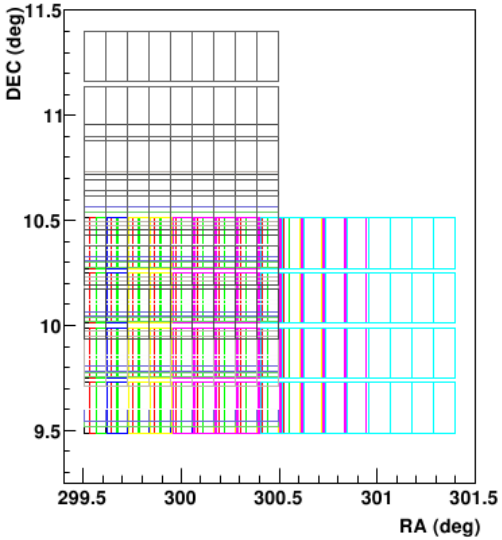
- Mostly reflections in the optical path (ghosts)
- Any optical effect affecting differently parallel and isotrope illumination (Small angle scattering, optical distortions ...)
- Varying filters



Critical in the transfer of average calibration to SN

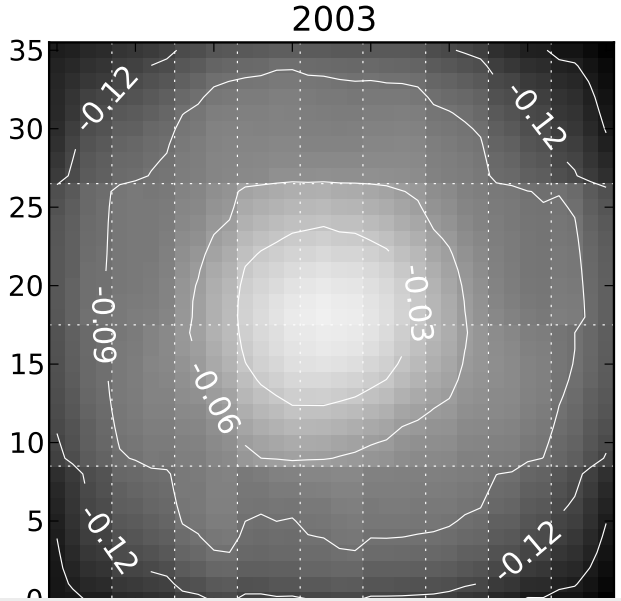
- Landolts and other standards observed at specific positions
- SN uniformly dispatched

Mapping the response: the grid observations



Dithered observations of dense stellar fields

- 13 exposures
- Logarithmically increasing steps from 1.5' to 1/2 deg
- 4-10 independent grid datasets /band
- $\rightarrow$ measure a correction δzp to the twilight flat-field



Observation model

$$m_{\mathrm{ADU}}(x, star) = m(x_0, star) + \delta zp(x)$$

- $m(x_0) \sim 100000$ nuisance parameters
- $\delta zp \sim 100$ parameters

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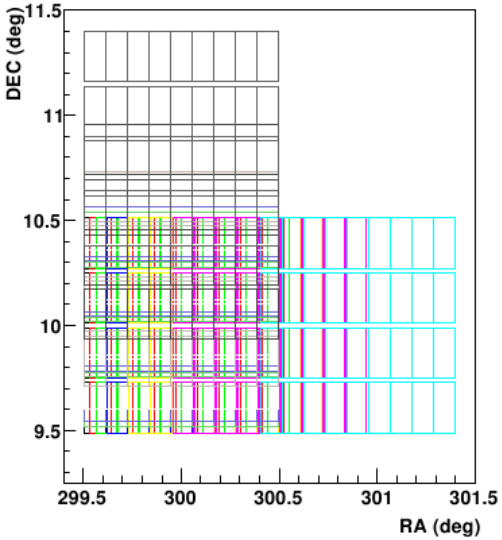

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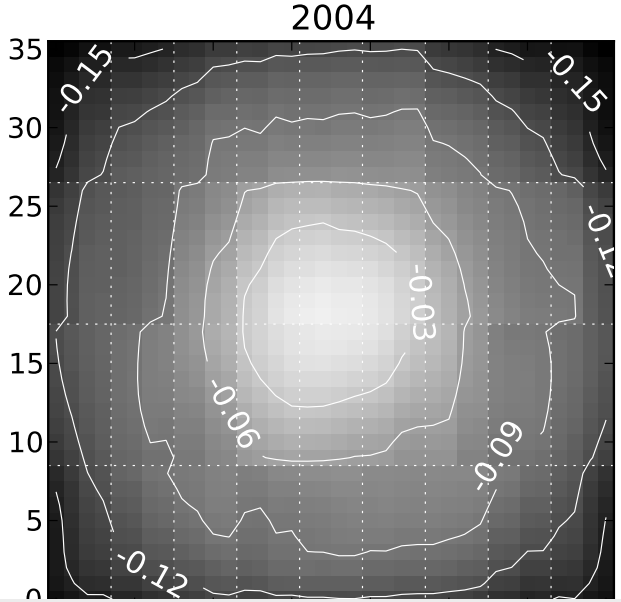

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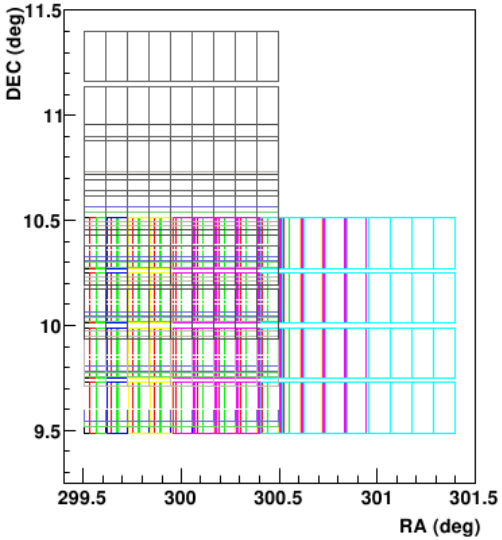

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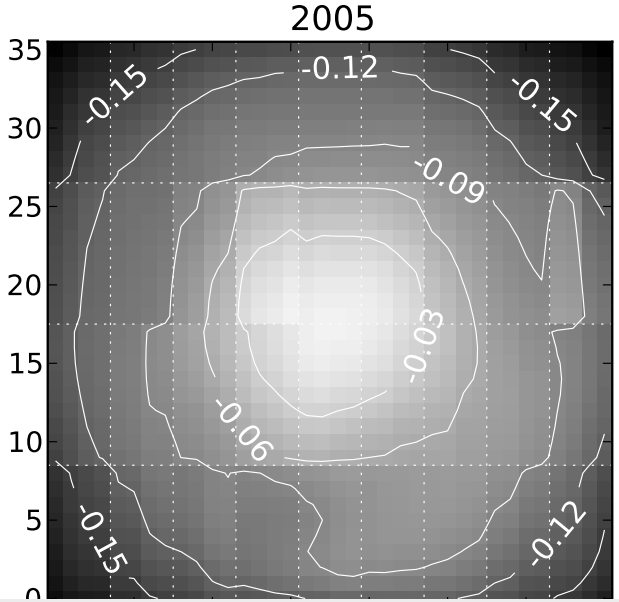

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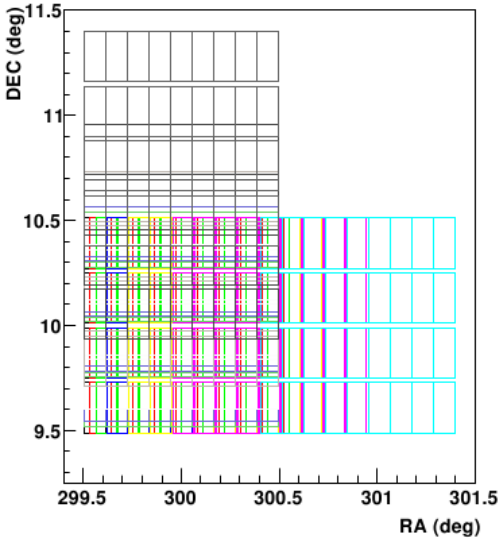

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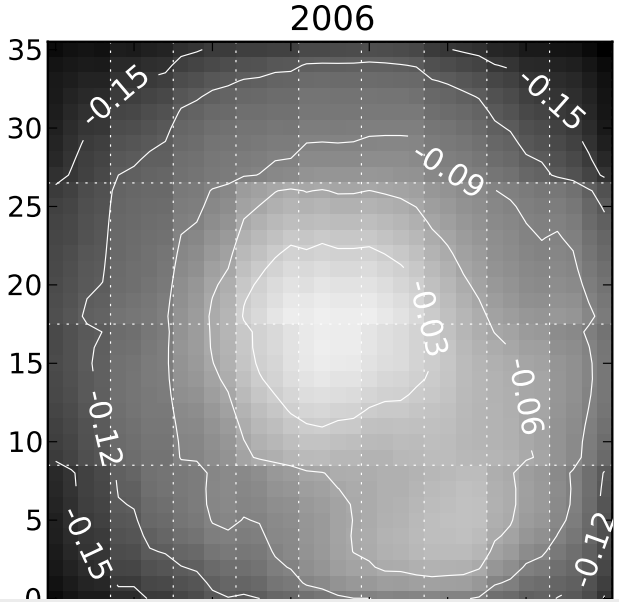

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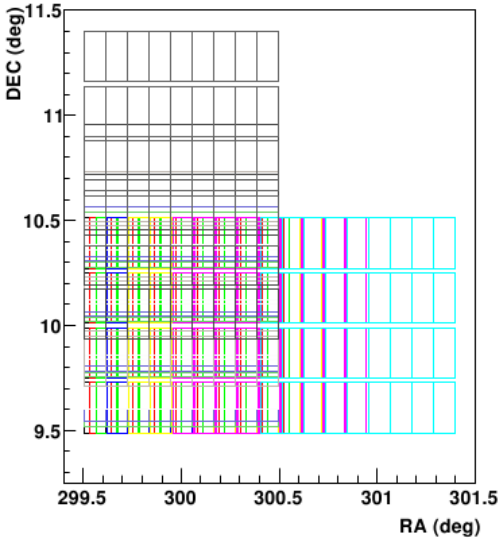

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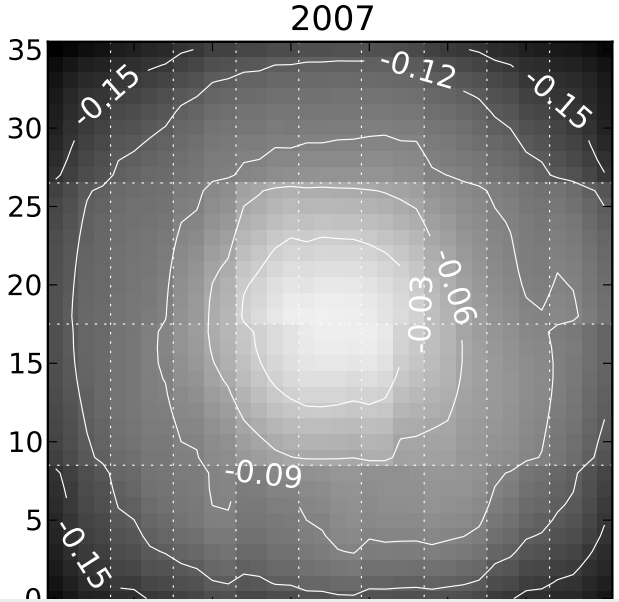

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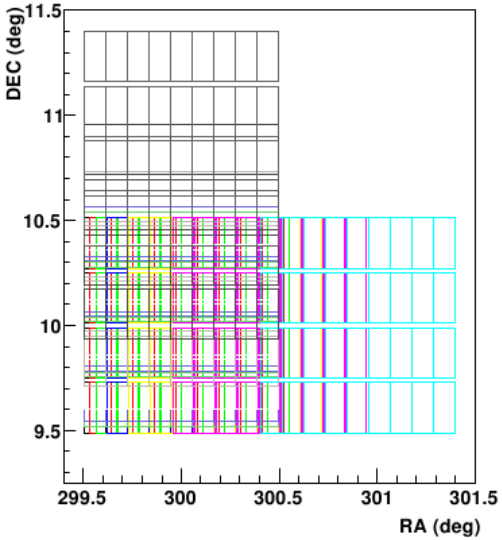

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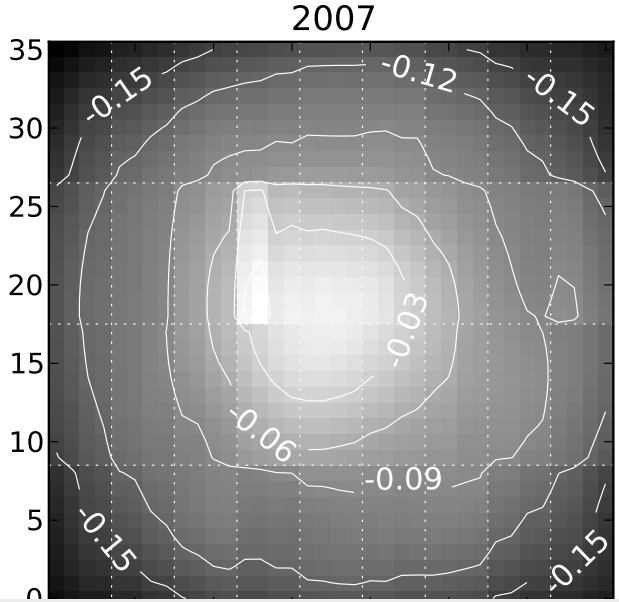

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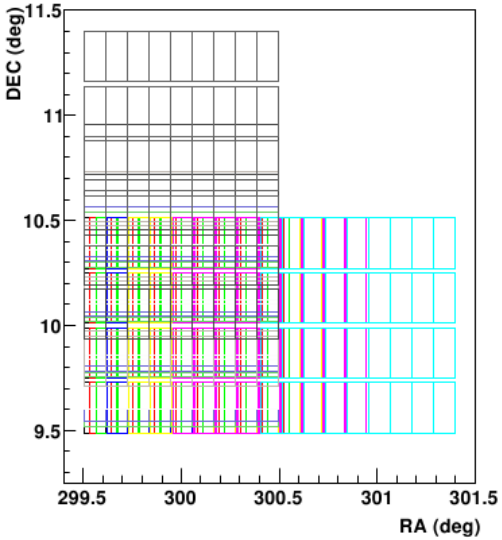

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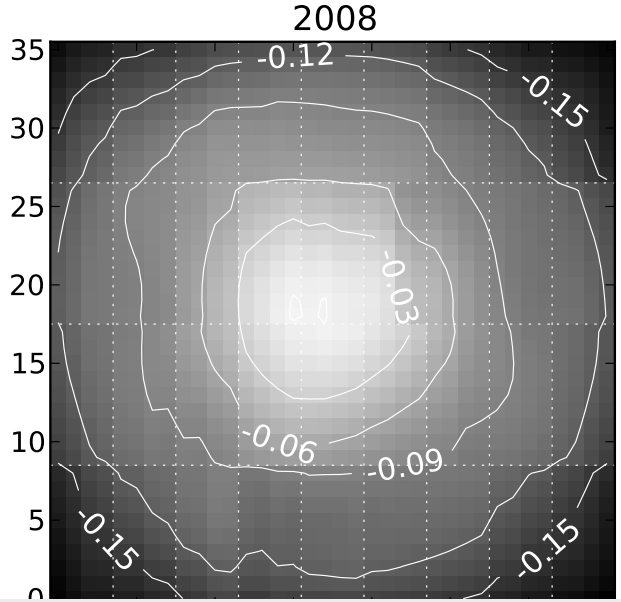

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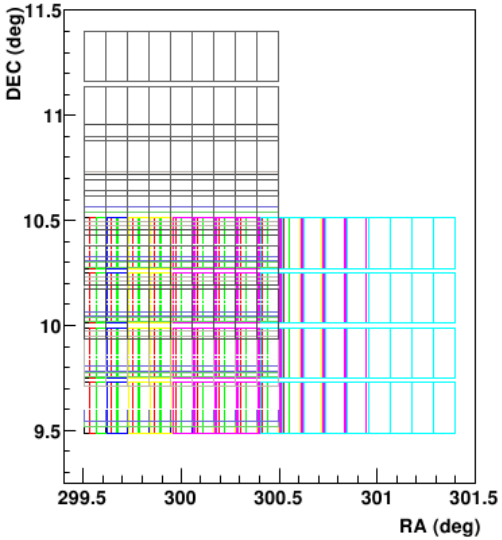

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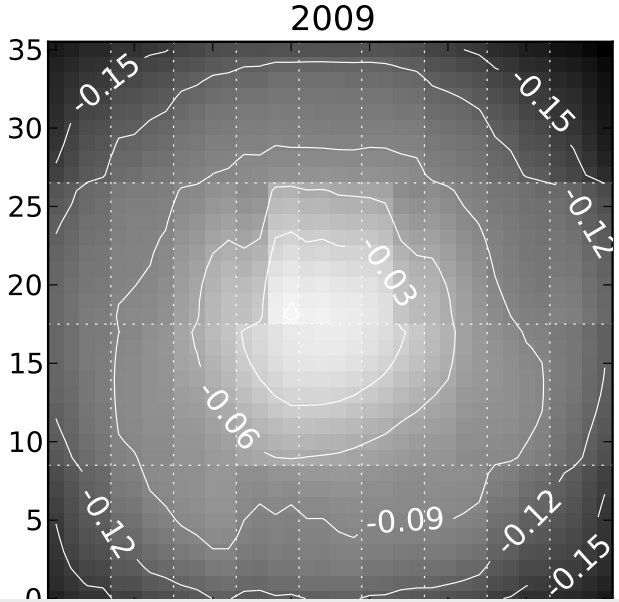

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Intrinsic limitations

Expensive

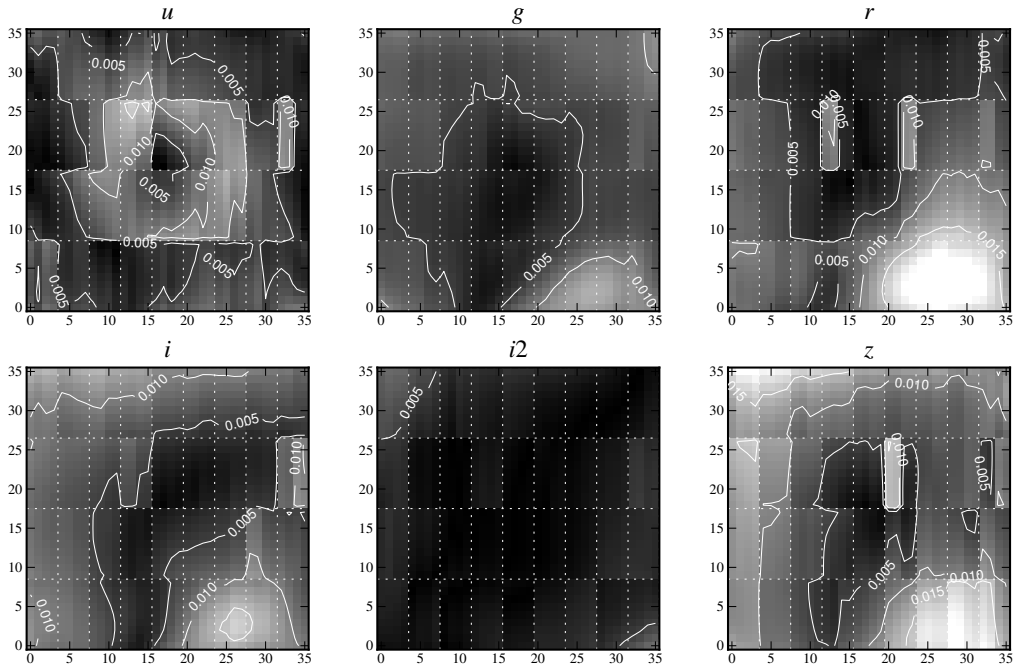
- External observations
- $\sim 1/2$ night for all bands
- Photometric time

Finite number of stars

- Limited resolution
- Limited precision

Solving for the zero point and response map at same time is poorly conditionned

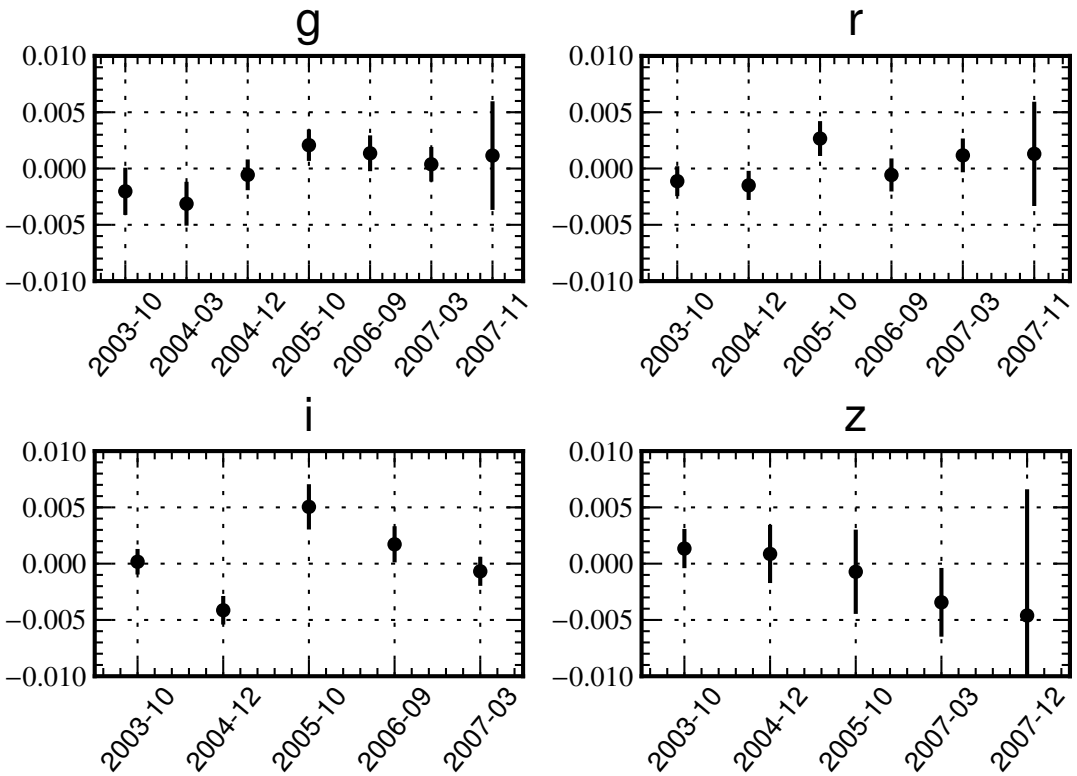
- Perfect photometric conditions required
- Radial gradient $\sim 1\%$



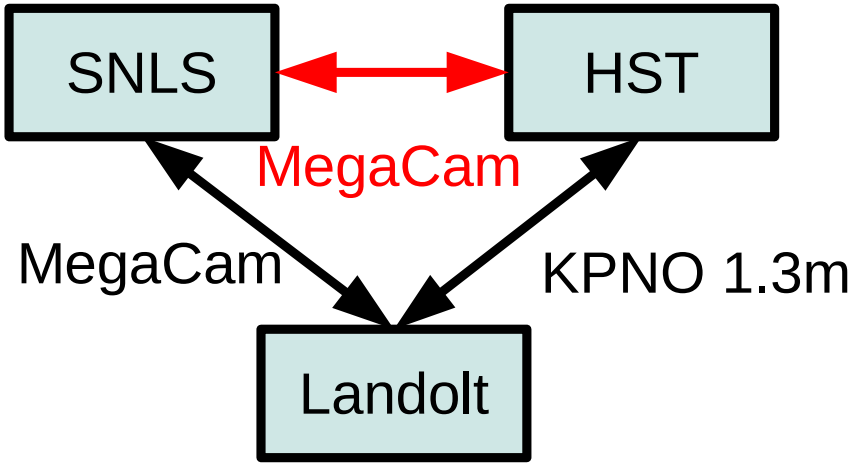
Results

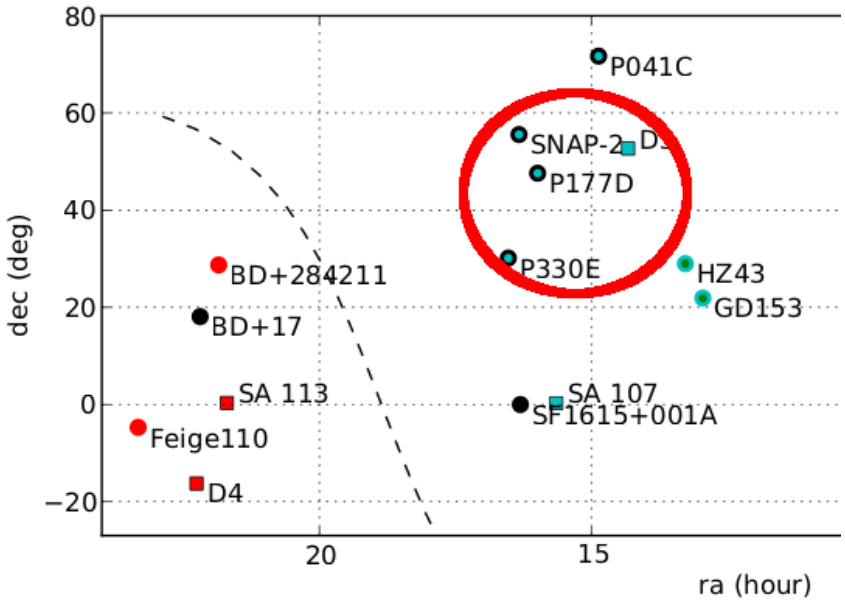
Evaluating the impact of flat-fielding errors on the calibration

- Independent observations → errors average out
- After selection ∼ 6 useable independent photometric corrections per band
- All epochs agree with *rms* < .3% in all bands



Step II: Anchoring to HST





Doubling the original path

- Uncertainty on the landolt to MegaCam transformation
- Direct observations of the CALSPEC Solar Analogs with MegaCam.

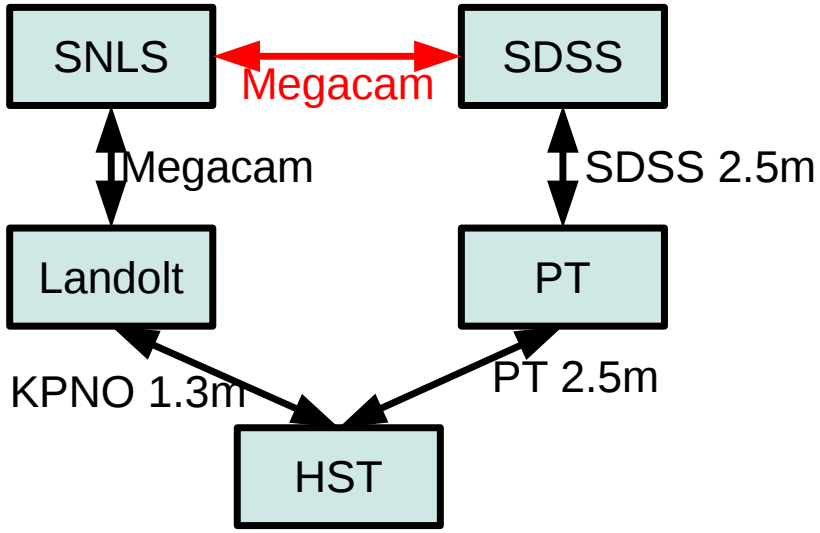
A small observation program

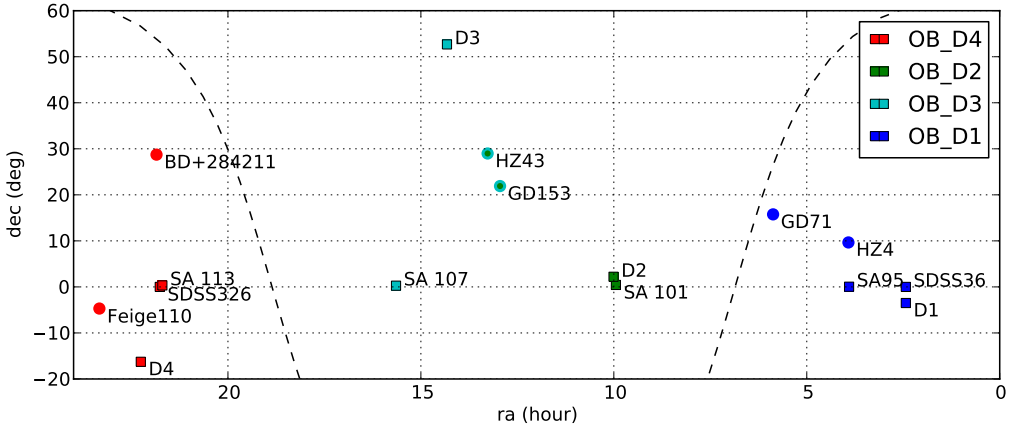
- 3 standards observed along with D3
- short observing group
- 4-5 nights / band at CFHT (5H)
- 5 mmag precision reached

Agreement between SA/BD+17 calibration

(mmag)	u	g	r	i2	z
dispersion between stars	27.5	5.7	5.7	0.5	4.3
dispersion between nights	12.3	4.7	6.1	5.4	11.7
offset	22.9	12.5	-8.6	-1.8	-2.9
uncertainty	14.4	4.0	5.2	4.4	7.5

Direct cross-calibration with the SDSS: a drastic shortcut

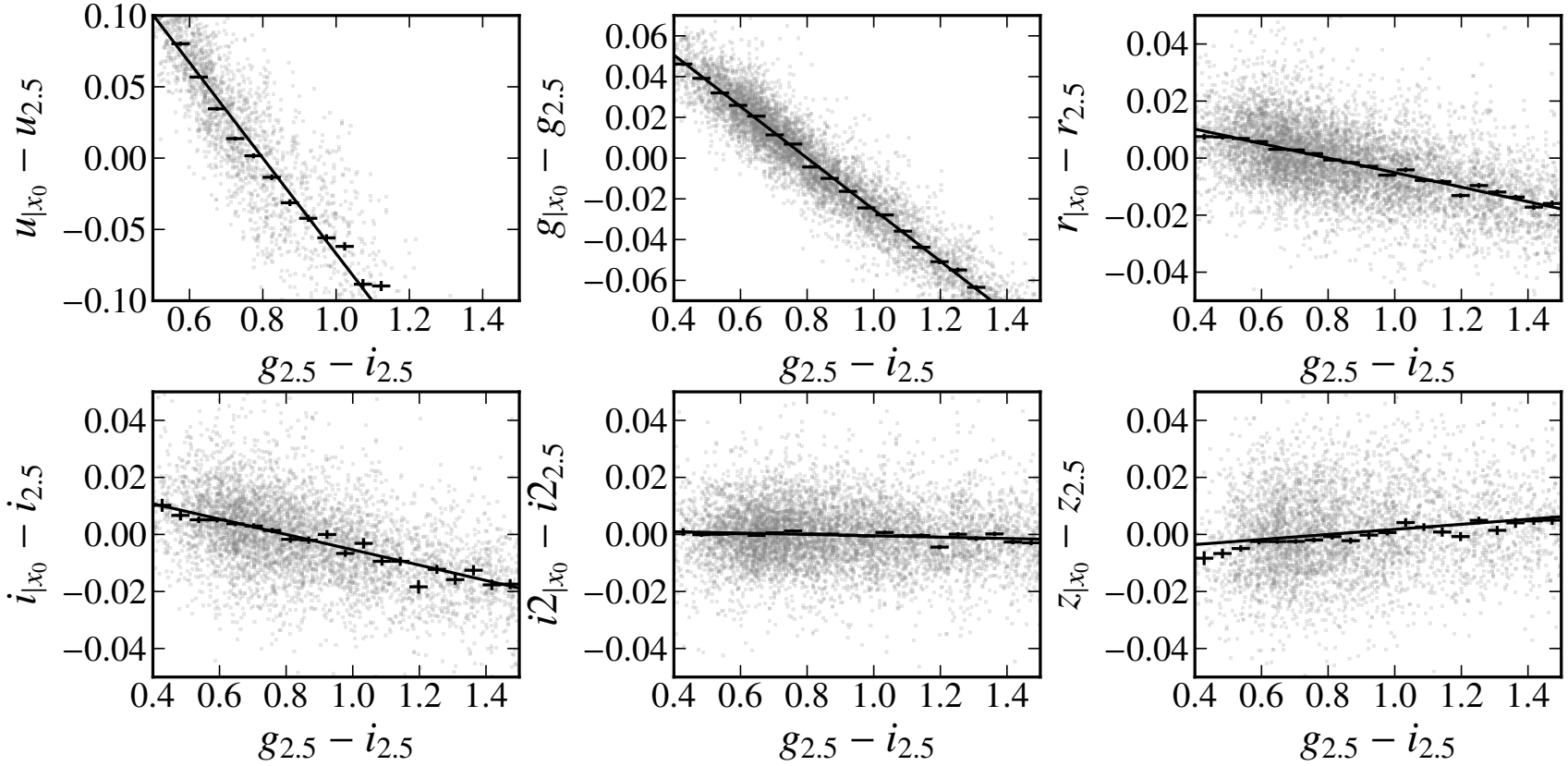




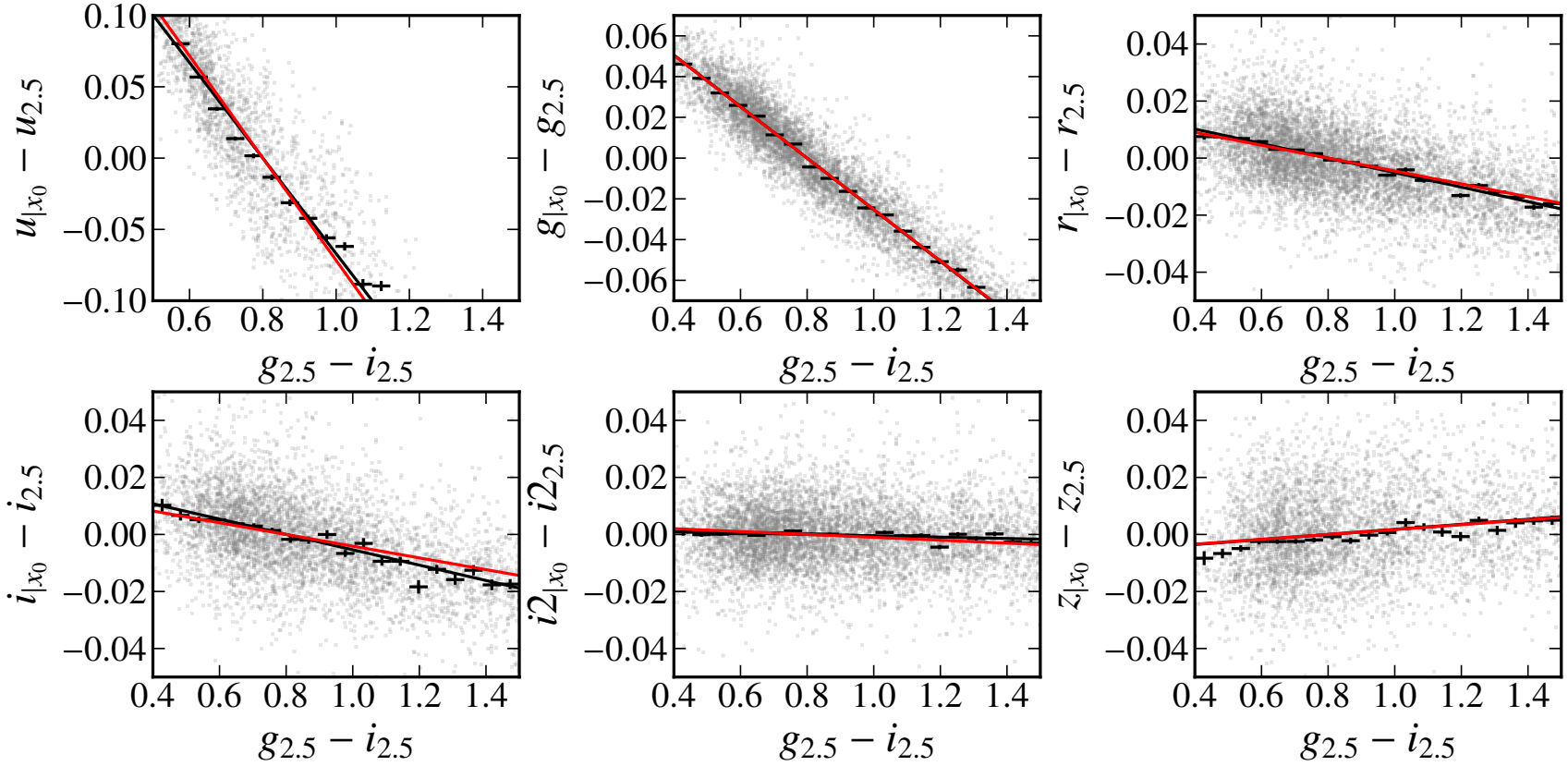
The observation program

- Original program includes 2 fields within the S82 (SDSS36, SDSS326) observed along with D1 and D4.
- Dithered observations
- Few epochs
- Completed in January 2011 by more numerous observations of D1/SDSS36

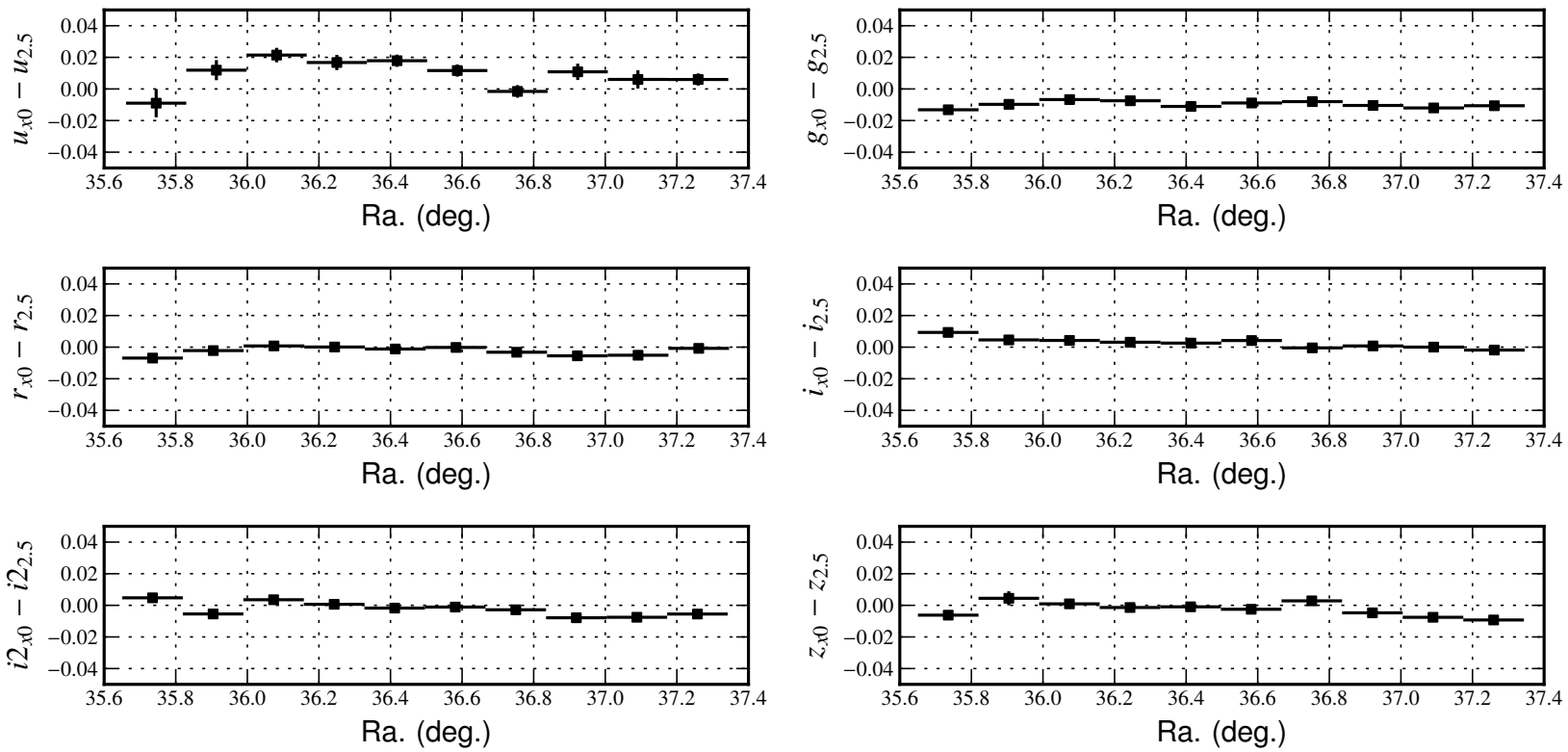
Measuring precise color transform



Checking passbands

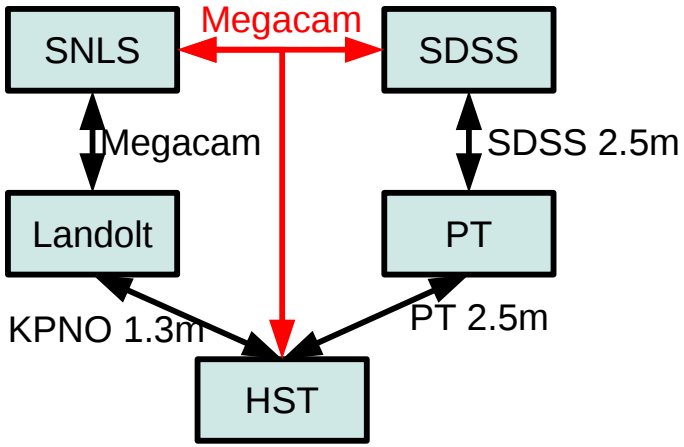


Checking uniformity



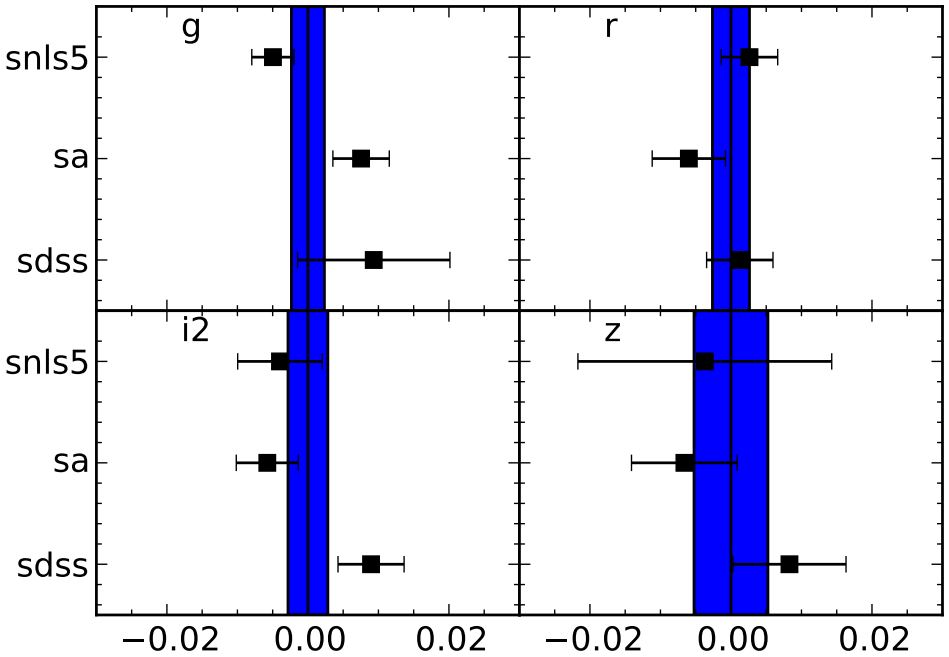
- Detect a (small) flat-fielding problem (PT related) in S82 catalog
- Confirm that MegaCam flat-fielding is good at the 5 permil level

Checking calibration



Closing the loop

- 3 independant path
- Do agree within announced error bars



band	combined uncertainties
g	0.002
r	0.003
i2	0.003
z	0.006

Conclusion

Redundant path to the HST flux scale

- Robust assessment
- Precision better than 5 mmag achieved
- Uncertainty on the flux reference itself now dominates

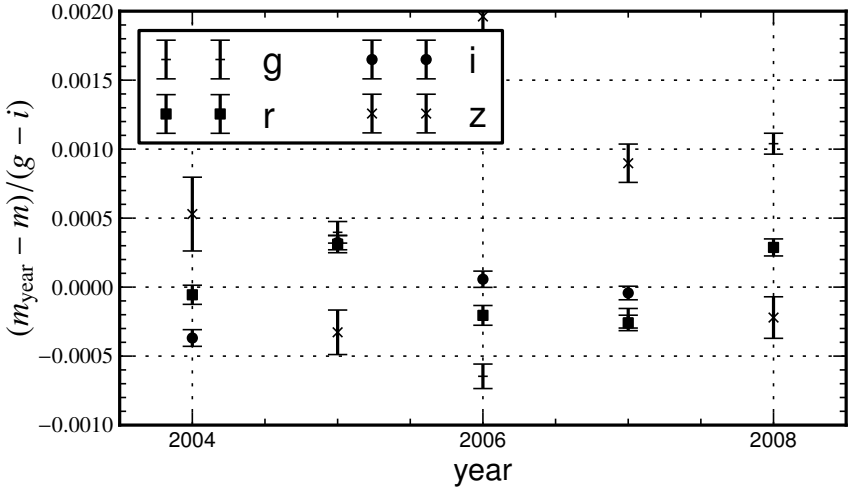
Pushing a classic calibration strategy, with intrinsic limitations

- Competition between accuracy and lost observation time
- Flat-fielding is difficult
- Accuracy becomes problematic around the 5 mmag level

Lessons learned

- Star-based photometric flat-fielding has intrinsic limitations.
- But it avoids the very tricky task of figuring out what the photometry do actually measure.
- Transfer of the average calibration between 2 fields is comparatively easier than the flat-fielding.

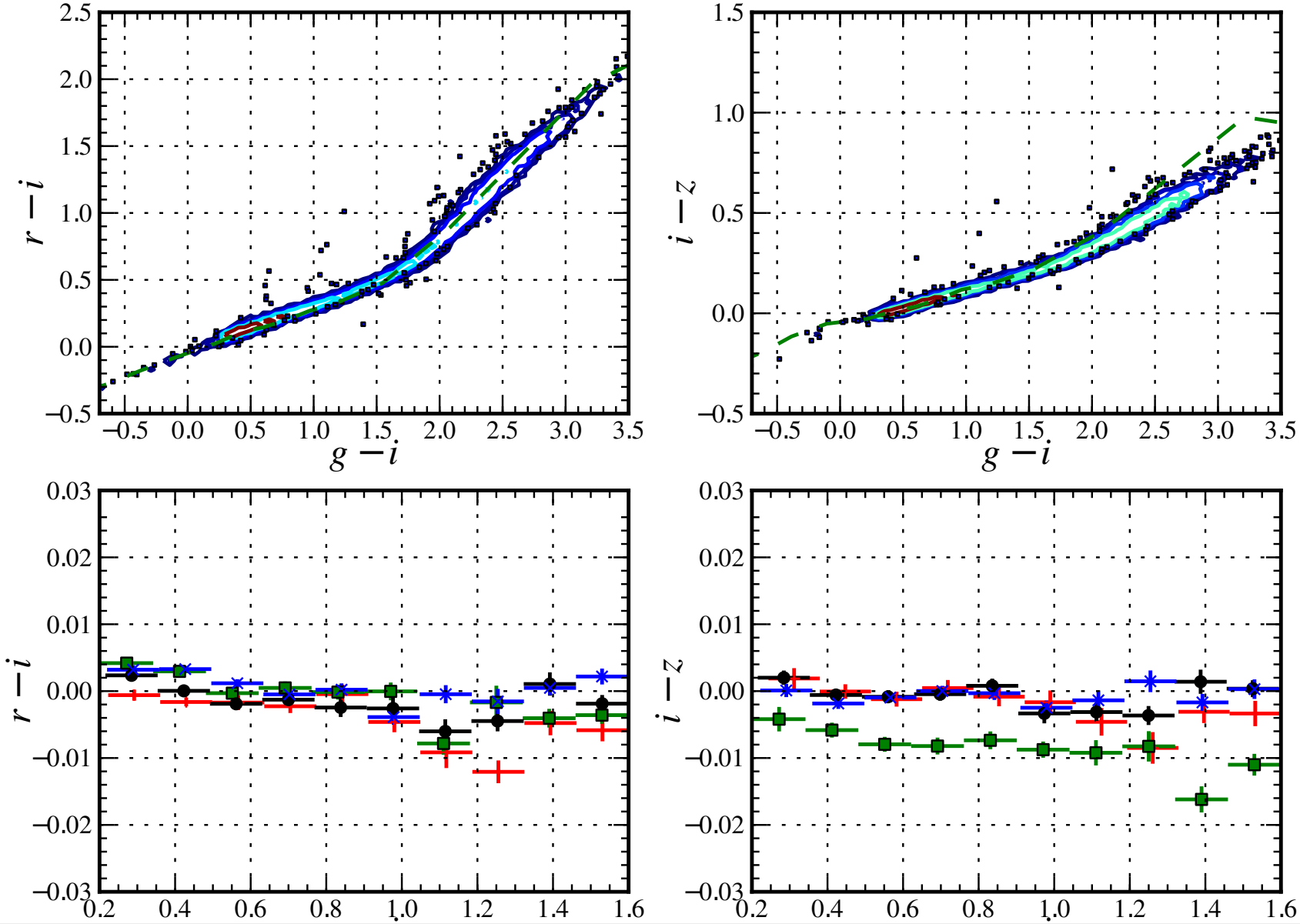
Filter evolution



No sizeable filter evolution

- Color-terms between yearly catalogs
- Evolution below .001 per unit of g-i
- 1 order of magnitude smaller than the CFHT/REOSC discrepency

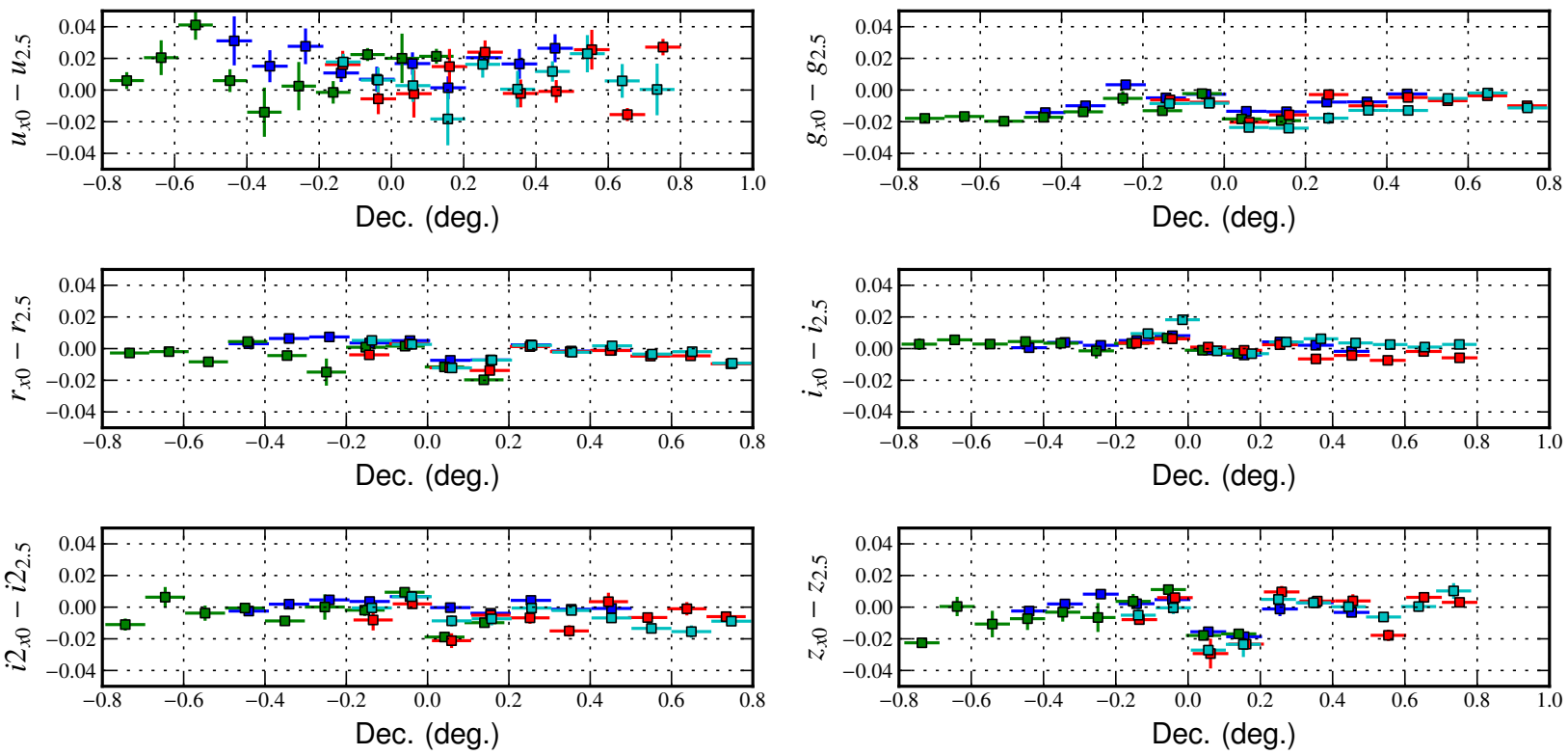
SNLS color diagrams



Response uniformity: SNLS-SDSS

- Flat-field problem in S82 corrected
- Much better, but features remain
- Arguably attributatble to SDSS

SDSS36



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